4.2.2 Drainage System Layout

Prior to alternative setting, drainage system layout should be made in accordance with future-projected land use, including design discharge calculation as an alternative of channel improvement.

Explanation:

Drainage systems (or storm sewer systems) aim at collecting and conveying runoff from rainfall in the urban area to watercourses. They include storm drains, inlets, manholes, pipes, culverts, conduits, on-site storage and detention/retention ponds, curbs and gutters, and other small drainage-ways that remove or help to manage runoff in urban areas.

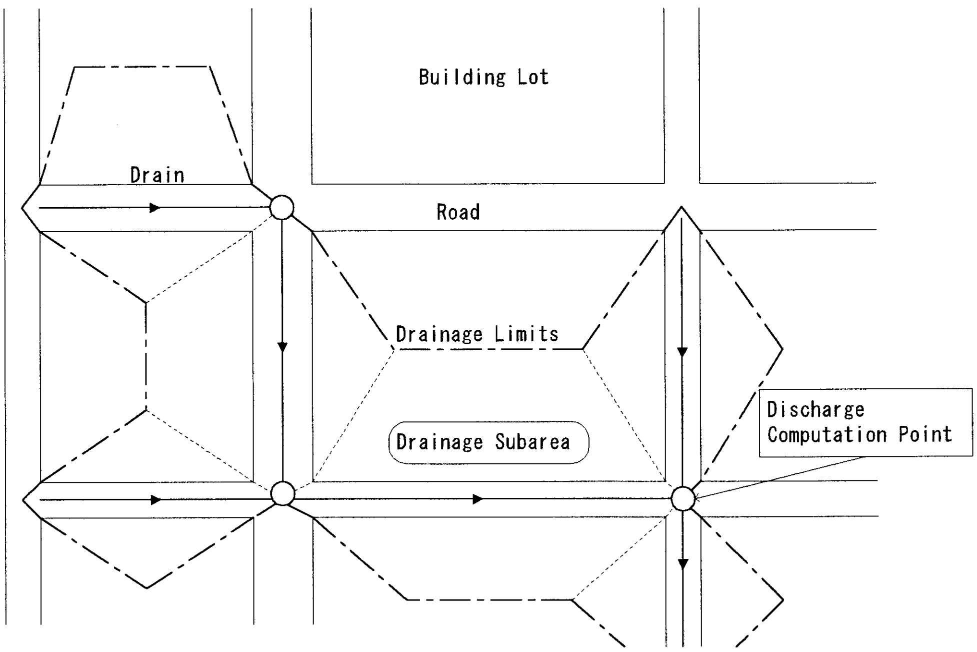
The first planning step for a drainage system is to establish an overall system layout that includes a plan of the area to be drained, showing roads, streets, buildings, other utilities, topography, and so on. When a part of the drainage area to be served is undeveloped and its proposed land development plan is not yet available, proper care must be taken to provide adequate junction structures that can later be connected to the constructed system serving the area.

The ordinary procedures of the system layout are as follows. The result of this procedure is an alternative with channel improvement.

(a) Prepare a drainage area map showing drainage limits, streets, impervious areas, and direction of surface flow.

(b) Divide the drainage area into sub-areas to the proposed stormwater inlets (refer to Fig. 4.4). Development of grading and drainage plans must be fully coordinated, because proper grading is the most important factor contributing to the success of the drainage system.

Fig. 4.4 Conceptual Layout of Drainage System



(c) Compute the area and imperviousness or average runoff coefficient of each area.

(d) Calculate the required capacity of each inlet, using the rational method or another similar method. Assume a 5 to 30-min. inlet time to be appropriate and compute inlet flows for a rainfall intensity that is obtained by using the intensity-duration curve in the design scale with the above concentration time.

(e) Beginning at the upstream end of the system, compute the discharge to be carried by each successive length of channel, moving downstream. At each point downstream where a new flow is introduced, a new time of concentration must be determined as well as new values of runoff coefficient and drainage area size.

(f) Using the computed discharge values, select tentative channel size for the slopes that normally should follow the ground surface. Once the channel sizes are known, flow velocities between input locations can be determined. Normally, these velocities are approximated by computing full-flow velocities. These velocities are then used to compute channel flow time for estimating the time of concentration.

(g) Make several trial drainage layouts until the most economical system can be selected.

4.2.3 Configuration of Alternatives

Alternative measures should be selected in due consideration of their applicability and effectiveness to the topographic conditions of the locality applied.

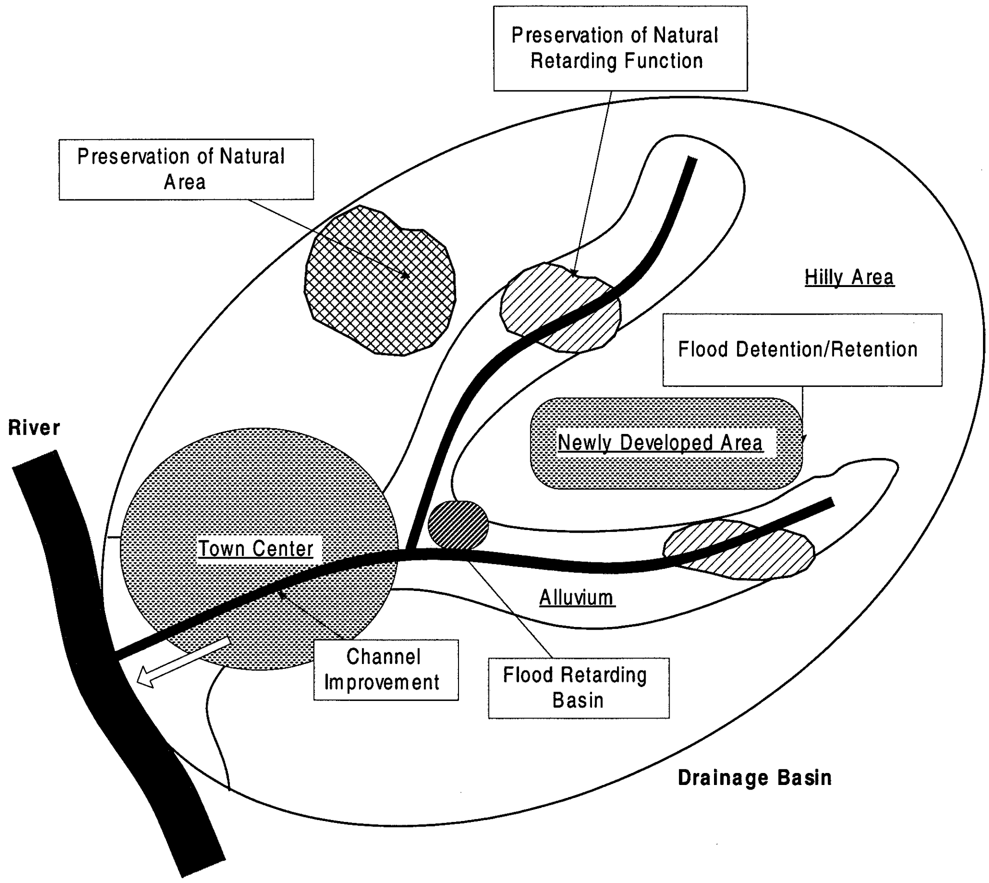
Explanation:

In general each countermeasure for alternative components has applicability to the particular topography as shown in Table 4.2. Fig. 4.5 illustrates the suitable location of each alternative measure in the drainage basin.

Table 4.2 Alternative Measures for Urban Drainage Improvement

Alternative Measures	Topography Applicable	Remarks
Structural measures		
channel improvement	any topography	Channel improvement is a core measure among drainage improvement works.
flood detention	mainly hilly area	On-site detention can be applicable to the flat topography.
flood retention	except for alluvium and high permeability of surface soil	Applicability closely depends upon the soil permeability and the geological formation (existence of gravel/boulder layer).
flood retarding	mainly alluvium	Valley-bottom plain or delta just upstream of urban area to be protected is a suitable site.
Non-structural measures		
land use regulation	mainly hilly area	Natural hilly area should be preserved for sound hydrological cycle.
	mainly alluvium	Natural retarding function should be preserved for protection of lower reaches.
land development guidance	any topography	Minimum size required for construction of detention/retention ponds should be lower so as to control the urban flood increment as much as possible.

Fig. 4.5 Conceptual Configuration of Alternative Measures for Drainage Improvement



4.3 Alternative Measures

4.3.1 Channel Improvement

Channel improvement is one of core structural measures among urban drainage improvement works, and environmental considerations should be given in the channel improvement so as to meet the current increment of people's expectations for environmental upgrades.

Explanation:

Among the earliest examples of drainage improvement works in most countries are urban drainage systems designed to convey urban storm flow away from populated areas to receiving waters. The channel improvement has been the core works of the conventional measures.

(1) Principal Concept of Conventional Channel Improvement

The basic concept of all drainage channel designs is to reduce flood area and duration by providing a smoother, steeper, or larger channel than the existing streams. Urban drainage channels are typically designed to eliminate flooding in the protected area for all floods smaller than or equal to design events. Ordinarily the improved drainage channels can be divided into the following three types.

Excavated Channels

Natural channels are often straightened, enlarged, or both to increase flow capacity or to allow for placement of other structures. Excavated channels traditionally have had straight alignments and trapezoidal cross sections.

Paved Channels

Channels designed to carry high-energy flows are frequently paved with non-erosive material, usually reinforced concrete. Paved channels are expensive to construct and are accordingly limited to areas with steep topography or where land costs are high. Concrete channels sometimes have rectangular cross sections to minimize land requirements, in particular, in the urban centers.

Side Slope Protection

Side slope protection is incorporated into channel design when erosive velocities are expected to occur and is widely used to prevent erosion along natural channels. Methods may be categorized as continuous or intermittent, with riprap revetment as an example of continuous protection while groins are intermittent designs. Vegetation, rock riprap and gabions are the most common materials for slope protection.

(2) Environmental Consideration*[4-2]

Compared with the natural streams, the urban drainage channels are quite small and artificial, and there could be few opportunities found out to be upgraded or enhanced as environmental resources/functions. In spite of these unfavorable situations, urban drainage channels and adjacent areas are often highly valued as aesthetic resources in the congested urban areas.

An assessment of existing visual quality and evaluation of visual impacts should be a part of planning and design. Visual impact assessment is accomplished by comparing with- and without-project conditions. Visual simulation of alternative designs can be developed through sketches, rendering (painting the design on a photograph), and a number of computer-assisted methods.

Use of vegetation and natural materials is one of the typical measures to protect and maintain visual quality. Vegetation and natural riverine substances, e.g., gravel and rock, can be used alone or in combination with structures to provide a more natural appearance. Minimizing the extent of bank and streamside clearing and using vegetation in the design preserve the natural appearance of the project setting. Restoration of excavated, eroded, and cleared areas can be performed as a part of construction activities.

Applicable species of vegetation to protect channel side slope areas depends on the frequency and duration of inundation, and velocity. In general the flood velocity on the side slope is expected not to exceed 1.8 to 2.4 m/s. Further research works of laboratory tests and literature survey are necessary for obtaining more detailed information on maximum permissible velocities for various grasses.

4.3.2 Flood Detention/Retention

Flood detention/retention facilities are the core structures for flood regulation, in contrast with channel improvement as a core structure for quick disposal of stormwater. There are various types of flood detention/retention facilities that have been constructed in many countries. Suitable selection of facility type should be made in accordance with the topography and the surface soil conditions.

Explanation:

Flood detention facilities are temporary storage for stormwater runoff. Stored flows are subsequently returned to the drainage system at a reduced rate of flow, when downstream capacity is available. The idea behind flood detention is to reduce the rate of delivery of stormwater at a discharge point. In contrast, flood retention facilities capture and dispose of stormwater runoff through infiltration and evaporation. The volumes of water captured are ultimately infiltrated and/or evaporated.

These facilities are generally applied for the following reasons.

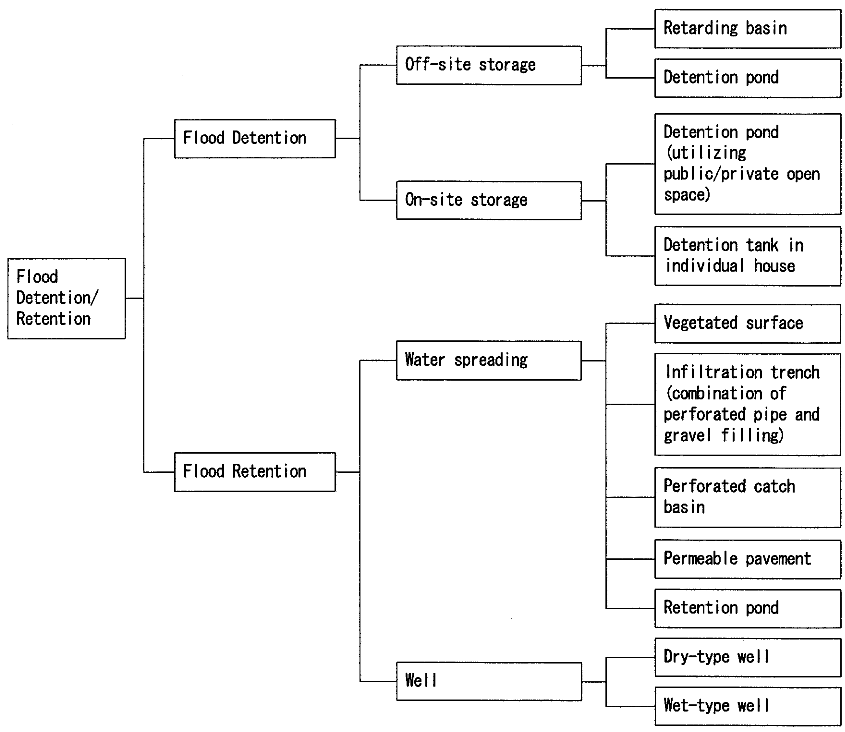
(a) Fulfil the external conditions of receiving water, such as poor flow capacity, difficulty of river improvement works and so on,

(b) Decrease the frequency and volume of overflows from drainage systems as an alternative flood control measure, and

(c) Minimize the cost of constructing new storm drains to serve a developing area in combination with on-site detention/retention facilities.

Flood detention/retention facilities can broadly be classified into the following types from water collection, storage, and disposal systems.

Fig. 4.6 Stormwater Detention/Retention Facilities*[4-3]



The following are general and typical features and their applicability of detention/retention facilities.

(1) Detention Facilities

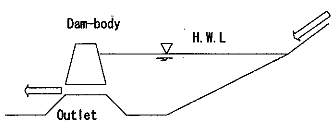
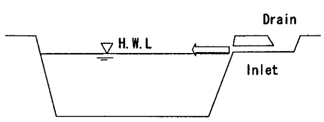
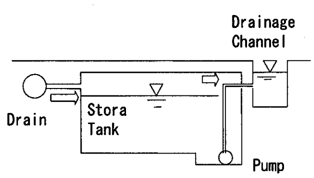
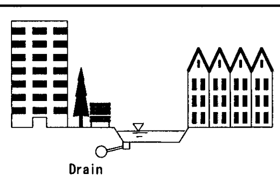
Detention pond delays excess runoff and attenuates peak flows in the surface drainage system. During peak flows, detention pond holds excess water until the inflow decreases and releases it during low-flow periods. Detention pond should be considered sedimentation that occurs during detention. Types of detention facilities include on-site and off-site.

On-site detention is the detention of stormwater at the source before it reaches a drainage network or receiving water. On-site detention pond is installed in open space between houses or flats, parking lots or recreational facilities. On-site detention facilities usually hold stormwater either in series or in parallel, as a group of facilities, within the collection system, since each volume of the storage is limited due to site constraint.

Off-site detention holds storm flow collected by the upstream drainage network, and releases it to the downstream drain. Functionally, the application of on-site detention differs little from off-site detention other than the location where the storage occurs.

Since off-site detention needs a collecting channel networks, construction of off-site detention facilities is suitable in the hilly areas with some gradient. On the other hand, since a drain network with only short distance can satisfactorily accomplish an on-site detention system, there are few topographic constraints for construction of on-site detention facilities. Thus on-site detention has effectiveness for solving flooding problems in the low-lying areas. The following table illustrates structural concept of various types of existing detention ponds*[4-3].

Table 4.3 Structural Type of Detention Pond

Type of Pond	Conceptual Layout	Remarks
Off-site Detention		
Small Dam		**Waterway is dammed up with earth or concrete dam-body, mainly adopted in the hilly areas.**
Excavation Pond		**Pond is made through excavation and stormwater is conveyed into it from the drain, mainly adopted in the areas of flat topography.**
Underground Storage		**Stormwater is detained in storage tank or drainage pipes situated under the ground. Method of storage tank is adopted for small-scale development in general.**
On-site Detention		**Open spaces between**
Depressed/Embanked Pond		**buildings, park and school ground are utilized for storage sites as a multiple usage. If the soil has high permeability, combination with retention is more effective.**

In connection with storage potential of on-site detention utilizing open spaces, Table 4.4 presents the maximum storage depth adopted in Japan. These are determined considering the limitation without interference of the existing or original land use. For instance, the maximum depth of 0.3 m for on-site detention utilizing school ground is determined in due consideration of walkable depth of pupils, especially in an elementary school. Further, the ratio of potential storage area to the catchment and the specific storage volume are also shown as a reference, based on the experiences in Japan.

Table 4.4 Storage Potential of On-site Storage*[4-3]

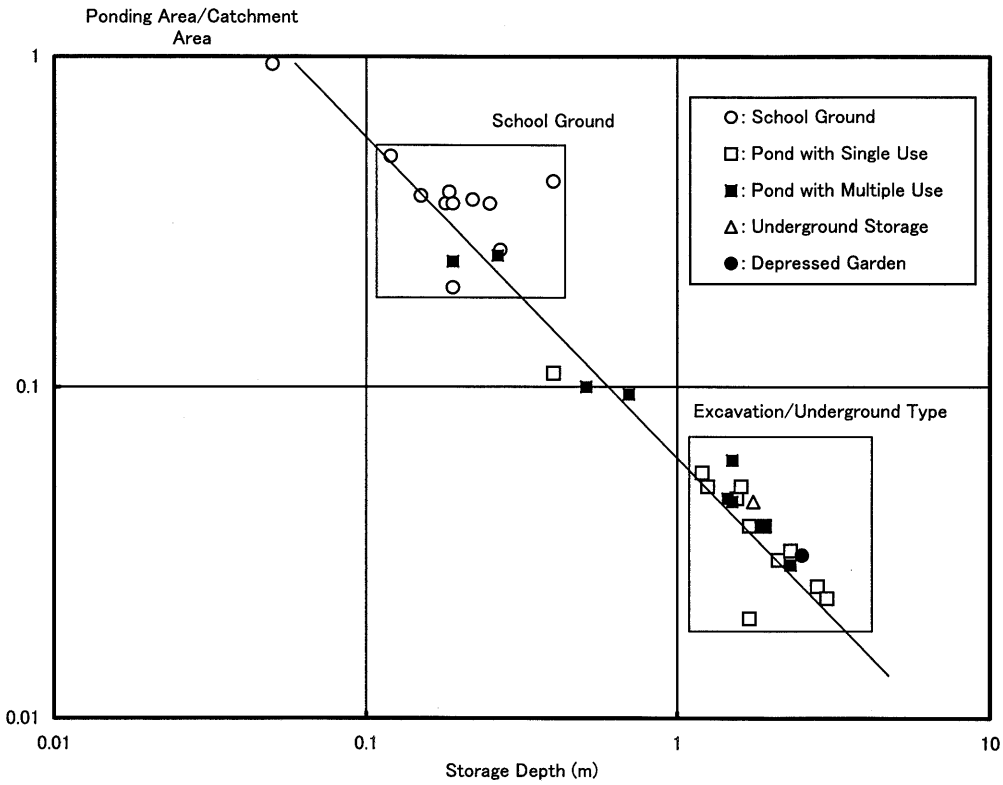
Land Use	Storage Site	Maximum Storage Depth	Potential Storage Area Ratio (Ponding Area / Catchment Area)	Potential Specific Storage Volume
Flat-type Housing	Open Spaces between Flats	0.3 m	40 %	1,200 m^3/ha
Parking Lot	Parking Area	0.1 m	80 %	800 m^3/ha
School	School Ground	0.3 m	40 %	1,200 m^3/ha
Park	Open Spaces	0.2-0.3 m	40-60 %	1,200 m^3/ha

Note: Specific Storage Volume = Storage Volume (m^3)/Catchment Area (ha)

The above figures are based on estimation on an assumption of possibility for usable area and depth in each land use. In addition, Fig. 4.7 illustrates the relationship between storage area ratio and maximum storage depth based on the actual data of existing detention ponds in Yokohama City, which is one of the major cities in Japan*[4-3].

This figure explains clear difference between on-site and off-site detention. Wide ponding area and shallow depth characterize on-site detention, while off-site detention is characterized by small ponding area and deep depth. This fact also supports the advantage of applicability of on-site detention to the low-lying areas.

Fig. 4.7 Relationship between Storage Depth and Ponding Area/Catchment Area, Based on Existing Detention Ponds in Yokohama City, Japan



(2) Retention Facilities

Source control relying on natural process may be considered as supplemental or alternative solutions to conventional urban drainage systems. Among the techniques of source control, stormwater retention has attracted attention during past two decades. Stormwater retention is often introduced with specific objectives such as flood control, combined sewer overflow abatement, groundwater restoration, prevention of ground subsidence, or drought prevention. Also decreased costs are sometimes mentioned.

So far, stormwater retention systems are widely used as source control of storm runoff but are prone to failure in unstable catchment because of clogging by sediment. In order to avoid the failure of clogging, the catchment to be introduced into the systems should be carefully selected. Thus the stormwater to be infiltrated should be collected only from the catchment of roofs, paved areas and thick grass garden, where little suspended solids are yielded.

Among various types of retention facilities, the water spreading type of infiltration is widely adopted over the world because of its more variable applicability compared with another well type of retention facility. Table 4.5 explains the typical facility layout of water spreading type*[4-4]. As for well type, infiltration wells are frequently used in areas which contain deep gravel deposits and thin superposed stratum of weathered material with low to medium permeability. They provide only a small extent of effective infiltration and storage but they can perform high infiltration intensity due to high permeability of the gravel. Installation of the well type, however, is clearly limited to the area where the thick gravel layer exists underneath.

The retention facilities are effective for flood control only in the areas of which soil has appropriate permeability. Based on the survey results of infiltration capacity as described in 2.5, flood retention plan will be established in the following procedures*[4-5].

(a) Preliminary layout of retention facilities,

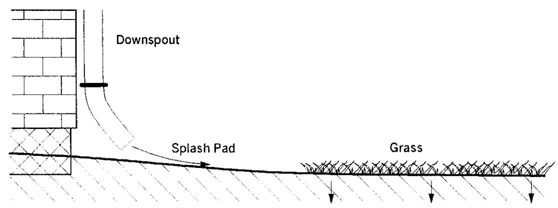
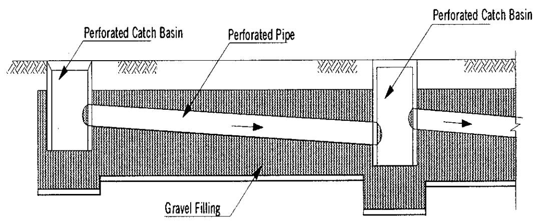
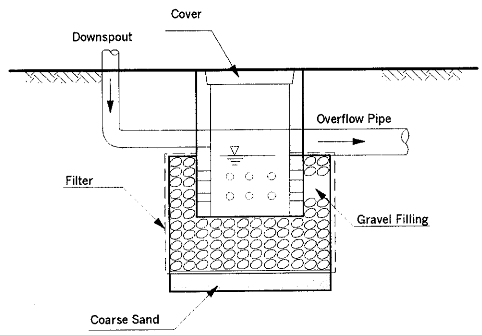
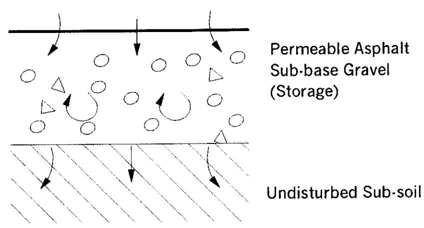
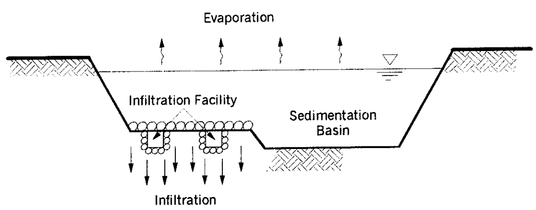
(b) Preliminary estimation of total infiltration capacity (Qb in m^3/hr), summing up the design infiltration capacity of facility (Qu_i) surveyed on site: for instance,
Qb (m^3/hr)= total number of perforated catch basin (units) $\times$ Qu_1 (m^3/hr/unit)+
total length of infiltration trench (m) $\times$ Qu_2 (m^3/hr/m)+
total area of permeable pavement (m^2) $\times$ Qu_3 ($m^3/hr/m^2$)+…

(c) Conversion from total infiltration capacity (Qb) into average infiltration intensity (Iave in mm/hr):
Iave (mm/hr)= Qb (m^3/hr)/{Catchment Area (ha) $\times$ 10}

(d) Evaluation of effectiveness of infiltration facilities:
The infiltration intensity mainly depends on the surface soil conditions. Actually an average infiltration intensity (Iave) is set up at approximate 3 to 35 mm/hr, based on the design reports of the existing infiltration facilities in Japan.

(e) Comparative study among alternatives, such as detention facilities, retention facilities or their combination.

Table 4.5 Typical Retention Facilities of Water Spreading

Retention Facilities	Structural Concept
<u>Vegetative Surface</u> Infiltration of stormwater through green surface is the technique that comes closest to natural infiltration of rainwater. Direct discharge of roof runoff to grass lawns by using an ejector connected to the downspout and splash pad with a slope away from the building is one of the solutions in residential areas.	
<u>Infiltration Trench & Perforated Catch Basin</u> Subsurface infiltration structures, soakaways, are the most common types of infiltration systems. They are basically holes in the ground filled with rubble or stones. The stormwater is stored temporarily in the cavities between the stones while it slowly percolates into the surrounding soil. They are typically long and narrow to minimize the surface area at the bottom that is supposed to clog with fines after some time, and to maximize the ratio between the effective infiltration area (the sides) and the volume.	
<u>Permeable Pavement</u> Road drainage through permeable asphalt and use of the sub-base for water storage has shown to be rather efficient in connection with roads for light traffic.	
<u>Retention Pond</u> During heavy rain stormwater can be stored in the basin, and slowly infiltrate through the soil layer and also slowly evaporate through water surface. This type of facilities frequently suffers severe clogging, so that proper and periodical maintenance is crucial.	

(3) Multiple Use

As guided by the Town and Country Planning Department*[4-6], multiple use of ponding areas might be a recommendable direction in order to enhance environment in and around the detention pond. The multiple use of detention ponds widely produces the following benefits, if some additional efforts are made.

(a) Leading to effective land use,

(b) Lowering of land development cost,

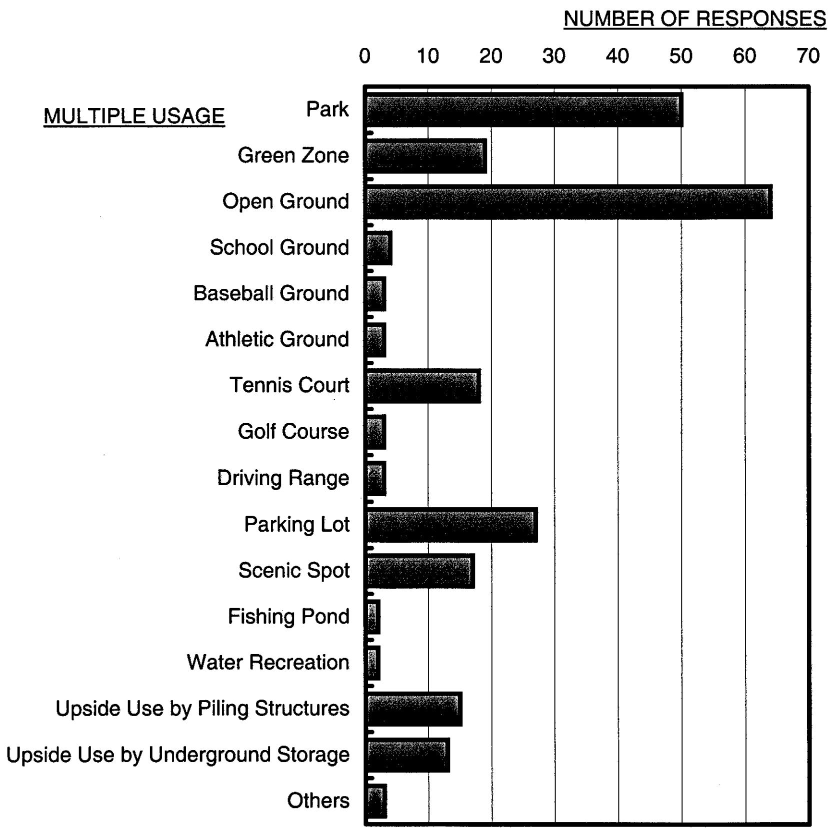
(c) Upgrading and creating of the urban scenery through introduction of greening and water-based beautification,

(d) Preservation of valuable natural environment through proper preservative planning and designing, and

(e) Enabling of proper maintenance because of high accessibility.

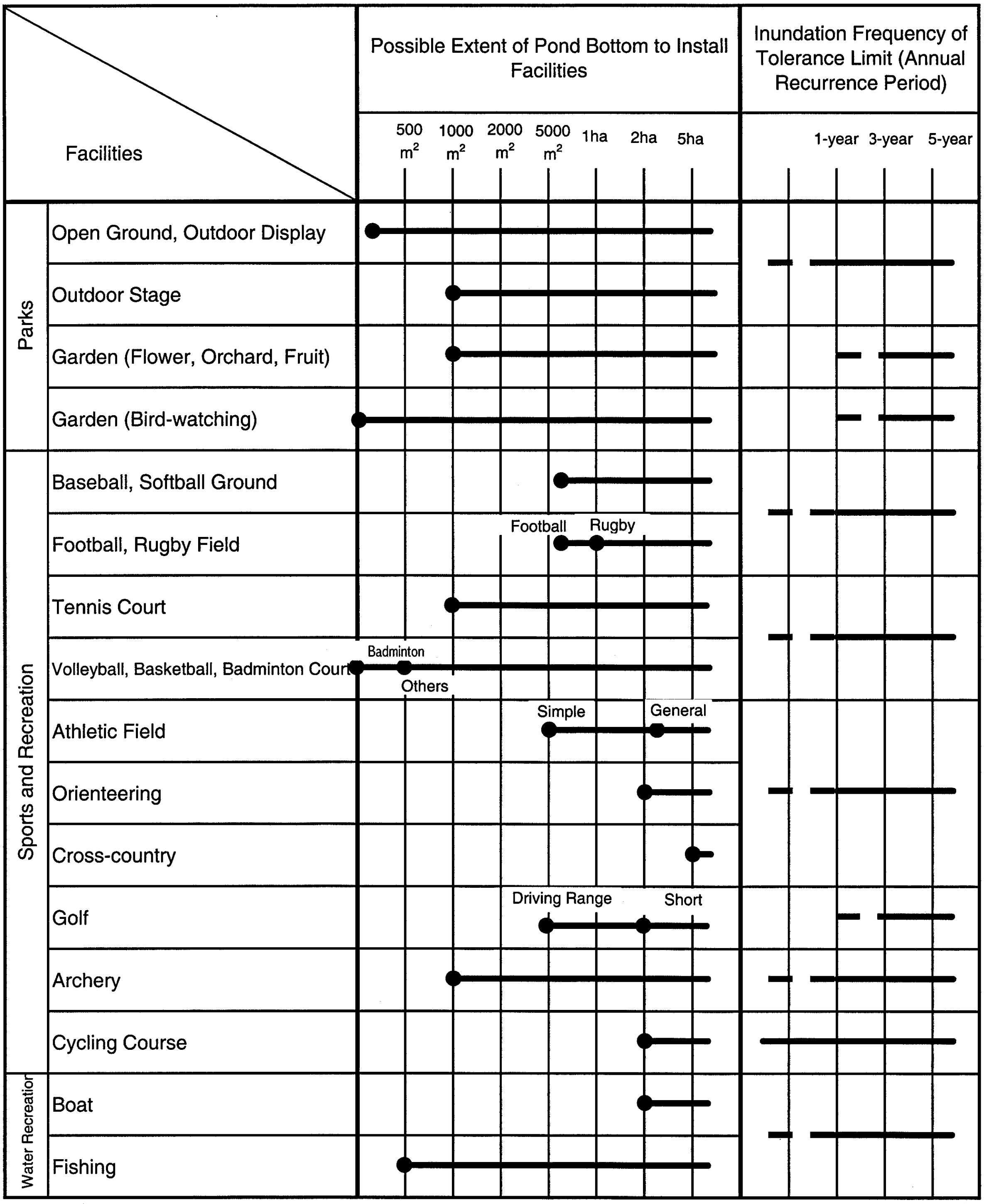
In the recent years, the requests of residents for multiple use of detention ponds have diversified, as environmental concerns of them have been increasing. The following figure shows those requests that are based on the questionnaire survey in 1993 Japan*[4-7].

Fig. 4.8 Resident's Request for Multiple Usage of Detention Pond



Further, the possibility of multiple use of detention pond mainly depends on the extent of pond bottom. The following table is a standard for multiple use of detention pond versus the extent of pond bottom and inundation frequency in Japan.

Table 4.6 Possibility of Facility Installation for Multiple Use of Detention Pond*[4-7]



(4) Considerations on Water Quality Management

In general, urban activities are continuously disturbing the natural environment, in particular, surface water pollution. The primary sources of urban nonpoint pollution are fertilizer from lawns and gardens, animal and bird feces, oil drippings, street litter, herbicide residues, atmospheric fallout of air pollutants, and dead animals and vegetation that have been either purposefully or incidentally placed on the land. In suburban areas, soil erosion and soil-absorbed pollutants are also sources of nonpoint pollution. As runoff from precipitation travels over the land, wastes and residues are entrained by the flow and carried to receiving surface water bodies. These residues may contribute significant amounts of suspended solids, BOD, nitrates, phosphates, fecal coliforms, and toxic metals to receiving waters.

The magnitude of the pollution load transported by urban runoff to receiving water bodies is comparable to that of treated sewage or even untreated sewage in some cases. The highest concentration of pollutants in stormwater is measured during the initial stages of storm runoff, during which the stormwater exhibits a so-called first flush effect by initially cleansing away the bulk of pollutants deposited during the preceding dry-weather period*[4-8].

The concentration of pollutants in stormwater depends on whether the stormwater reaches to the receiving water through the sewer systems. In Malaysia, so far there are three types of existing stormwater drainage systems, namely,

(a) Flow from storm sewers in separate sewer systems,

(b) Flow from combined sewers, and

(c) Non-sewered overland flow.

Table 4.7 gives a comparison of the quality of related sewer systems, which was observed and compiled in the Unite State. Surface runoff in this table might be equivalent to the non-sewered overland flow and the flow from storm sewers, which are mentioned above. Thus the most critical issue might be how to manage the water quality of flow from combined sewers.

Table 4.7 Comparison of Typical Values for Stormwater Discharges*[4-9]

	TSS	BOD	Total Nitrogen	Total PO_4-P	Fecal Coliforms
Surface Runoff	415	20	3.10	0.6	13,500
Combined Sewage	370	115	9.10	1.2	670,000
Sanitary Sewage	200	200	40	10	-

Note: All values mg/L except fecal coliforms that are organisms/100mL.

Methodology and management technology on stormwater quality management has not yet been established even in the developed countries. Further, the major concerns in the countries differ from each other since the needs of the management closely depend on the backgrounds of historical sewer improvement, the climatic conditions and the severity of water pollution.

In order to establish the sound stormwater quality management, the following studies and research works needs to be made as an initial stage.

(a) Water quality monitoring on drainage channel flow in various types of sewer systems to identify the problems on stormwater quality management, and

(b) Water quality monitoring at the stormwater control structures such as detention/ retention facilities for evaluating the effects of water quality control.

After evaluation of monitoring results, appropriate storage volume for water quality control shall be determined considering topography, head and space permit. For water quality control in the pond, however, quite long period of several days is generally required for residence time. On the contrary, the stored stormwater has to be discharged out immediately after storm subsidence because the enough storage space should be maintained for another storm. Thus stormwater quality control by utilizing the detention pond is a difficult issue in the tropical countries.

The determination of the best management practices for treating urban stormwater is one of the important issues on water quality management.

The best management practices (BMPs)*[4-9] for urban runoff are non-structural or low structurally intensive alternatives for the control of urban runoff pollution at its source. BMPs are less costly and more efficient than the structural alternatives to reduce pollutant loads and they include the benefits of soil erosion control, flood control, and cleaner neighborhoods. The success of such measures in controlling urban runoff pollution is very much dependent however, on educational programs and passage of legislation or ordinances to encourage or force people to comply with intended BMPs. This approach is categorized into in-process technology, while wastewater treatment facilities are categorized into end-of-pipe technology. The following preventive measures, construction controls, and corrective maintenance and operation practices are suggested for BMPs.

<u>Preventive Measures</u>

(a) Utilization of greenways and detention ponds

(b) Utilization of pervious areas for recharge,

(c) Avoidance of steep slopes for development

(d) Maintenance of maximum land area in a natural, undisturbed state

(e) Prohibiting development on floodplains

(f) Utilization of porous pavements where applicable

(g) Utilization of natural drainage features

<u>Soil Erosion Control at Construction Sites</u>

(a) Minimizing of area and duration of soil exposure

(b) Protecting of soil with mulch and vegetative cover

(c) Increasing of infiltration rates

(d) Construction of temporary storage basins or protective dikes to limit storm runoff

Corrective Maintenance and Operational Practices

(a) Control of litter, debris, and agricultural chemicals

(b) Regular street sweeping and repair

(c) Proper use and maintenance of catch basin and drainage collection systems

(d) On-site retention or detention of stormwater runoff

4.3.3 Flood Retarding Basin

Flood retarding basin can be an effective structural measure to attenuate the perk discharge collected by the drainage network, if proper site and extent for a basin are prepared.

Explanation:

Natural waterways originally have their retarding function along the alluvial plain. Functional mechanism of flood retarding is quite similar to flood detention. Flood retarding is regarded as a function rather centralized to a main stream, while flood detention is a function dispersed over a basin due to scattering the facilities. Thus, sometimes flood retarding effects can be expected much higher than flood detention/retention.

The suitable location of flood retarding basin is just upstream of the area to be protected. Flood retarding basin is an artificial facility to preserve or strengthen the natural retarding function by excavation of the basin bottom, if necessary, and construction of the diking system encompassing the basin. The common control structures consist of inlet structure of overflow section, which starts to convey floodwater into the basin when the channel water-level reaches a predetermined level, and outlet structure that discharges stored floodwater back to the channel.

The retarding basin also could play a role to integrate the detention ponds to be scattered over the basin in the following manner.

(a) The possible land development area in an intensively urbanizing basin should be predicted beforehand.

(b) Based on the prediction, the necessary volume to be controlled by the retarding basin should be computed, and the necessary structure should be designed at the suitable site.

(c) The retarding basin should be constructed as a preceding investment, and the cost should be allocated to the following development activities.

As a result, the developers have to pay the allocated cost instead of construction of detention pond. For the developers, the cost to pay might be lower than the construction cost of detention pond. Further, the minimum development area required for pond construction could be easily lowered, if this system properly works out.